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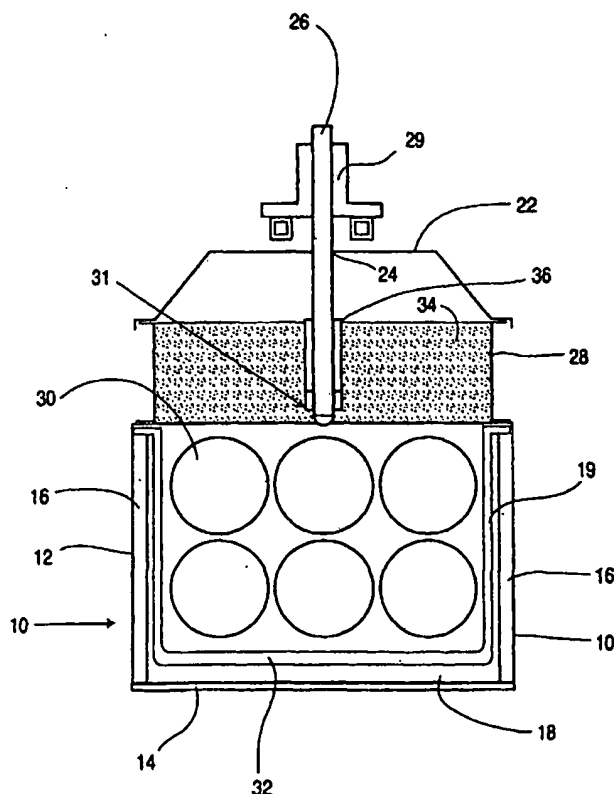
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[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR VITRIFICATION OF CONTAMINATED SOIL OR WASTE



(57) Abstract: A process for vitrifying contaminated waste material (30) includes providing a container (10) including an insulating lining (16), placing the waste material (30) in the lined container (10), subjecting the material (30) to an electric current to heat and melt the material (30), cooling the molten material to form a solid vitrified mass, and disposing said mass. The mass is disposed while contained in the container (10). The insulating lining (16) may comprise one or more layers of a thermal insulating material (19), one or more layers of refractory material (18), or a combination thereof.

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1 **APPARATUS AND METHOD FOR VITRIFICATION OF**
2 **CONTAMINATED SOIL OR WASTE**

3
4 **BACKGROUND OF THE INVENTION**

5
6 **FIELD OF THE INVENTION**

7 [0001] The present invention relates to a method and apparatus for vitrification of soil or
8 waste materials. More specifically, the invention relates to an apparatus that comprises a
9 vitrification chamber and disposal container, which enables a one step disposal method for
10 contaminated materials.

11
12 **DESCRIPTION OF THE PRIOR ART**

13 [0002] The use of vitrification methods for safely disposing contaminated soil or waste
14 materials (hereinafter referred to as material to be treated) is known in the art. Examples of
15 such methods are provided in US patent numbers: 4,376,598; 5,024,556; 5,536,114;
16 5,443,618; and, RE 35,782. The disclosures of these patents are incorporated herein by
17 reference.

18 [0003] Generally, the known vitrification methods involve placement of the material to
19 be treated into a vitrification chamber or vessel. Electrodes are then introduced into the
20 material and a high current is supplied there between. Application of the current is continued
21 until the temperature of the material is raised to the point where the material begins to melt
22 and is continued until the material is completely melted. In certain cases, other additives may
23 be required to provide an initial electrically conductive resistance path through the material to
24 be treated if such material is not capable of adequate current conduction. Once the resistance
25 path is initiated and melting of the material begins, the molten material itself will continue
26 current conduction.

27 [0004] In the course of melting the material, hydrocarbon components are destroyed or
28 vaporized and the gases are normally vented through a suitable scrubber, quencher, filter or
29 other known device or method.

30 [0005] Once the material is sufficiently melted and all hydrocarbon components are
31 treated, the electricity supply is terminated and the molten material allowed to cool. The
32 cooling step then results in a vitrified and/or crystallized solid material. In this manner,

1 contaminants are immobilized within a solid, vitrified mass thereby ensuring containment of
2 the contaminants and facilitating disposal of same.

3 [0006] In the known methods, vitrification is accomplished within a complex crucible
4 apparatus or within a pit dug into the soil. In US patent 5,443,618, an example is provided of
5 a vitrification apparatus comprising a chamber that is either permanently in place (as in a
6 treatment facility) or one which can be dismantled and reassembled at desired locations. In
7 each case, the molten mass is removed from the chamber and processed further separately.
8 Such further processing may involve burial of the vitrified mass or other type of disposal.
9 The apparatus known in the art for conducting vitrification process are normally complex
10 structures including various electrical supply systems, waste feed systems, molten glass
11 discharge systems, cooling systems and venting systems. With such systems, require the
12 removal of the melted mass while in the molten state, hence requiring the above mentioned
13 molten glass discharge systems. In these cases, the melt is either poured or flowed out as a
14 molten liquid into a receiving container.

15 [0007] In US patents 4,376,598 and RE 35,782, vitrification processes within a pit are
16 described. In this case, the material to be treated is dumped into a pit or trench in the ground
17 and a soil or other type of cap is placed as a cover. Electrodes are then introduced to conduct
18 the vitrification process as described above. Once the process is completed, the vitrified mass
19 is left buried in the ground. As will be appreciated, certain contaminants such as radioactive
20 waste etc. cannot safely be disposed in this manner as they must be disposed of in designated
21 burial locations.

22 [0008] Therefore, there exists a need for a vitrification apparatus and method that
23 overcomes various deficiencies in the prior art.

24 SUMMARY OF THE INVENTION

25 [0009] Thus, in one embodiment, the present invention provides a process for vitrifying
26 waste and/or hazardous material comprising:
27

- 28 - providing a container for containing said material, said container including an
29 insulating lining;
- 30 - placing said waste or hazardous material in said container;
- 31 - inserting at least one pair of electrodes into said waste or hazardous material;
- 32 - sealing said container with a first cover;

1 - passing current between said pair of electrodes for a time and power level so as to
2 melt said waste or hazardous material; and,
3 - cooling said molten material until such material forms a solid, vitrified mass.
4

5 [0010] In another embodiment, the present invention provides a container for vitrifying
6 waste or hazardous material comprising a box, said box including an inner lining comprising
7 one or more layers of a thermal insulating material, one or more layers of a refractory
8 material or a combination thereof.
9

10 BRIEF DESCRIPTION OF THE DRAWINGS

11 [0011] These and other features of the preferred embodiments of the invention will
12 become more apparent in the following detailed description in which reference is made to the
13 appended drawings wherein:

14 Figure 1 is an end cross sectional elevation view of a container according to an
15 embodiment of the present invention.

16 Figure 2 is an end cross sectional elevation view of an apparatus including the
17 container of Figure 1 when in use according to an embodiment of the invention.

18 Figure 3 is an end cross sectional elevation view of an apparatus including the
19 container of Figure 1 when in use according to another embodiment of the invention.

20 Figures 4a to 4d are end cross sectional elevation views of the apparatus of Figure 3 in
21 various stages of the melting process of the invention.
22

23 DESCRIPTION OF THE PREFERRED EMBODIMENTS

24 [0012] As discussed above, traditional vitrification processes have been conducted in pits
25 or in complex chambers. The present invention, however, provides a container into which
26 the contaminated material to be treated is placed and in which the vitrification process is
27 conducted. Moreover, the container is manufactured in such a manner as to be easily
28 disposable once the vitrification process is completed. This avoids the need to remove and
29 handle the molten or vitrified mass, thereby providing a safe and easy means of waste
30 disposal.

31 [0013] The container of the present invention may be used in virtually all types of
32 vitrification processes. For example, the container and process may be used for various

1 contaminant types such as heavy metals, radionuclides, and organic and inorganic
2 compounds. Concentrations of the contaminants can be of any range. Further, the invention
3 can be used with all soil types such as, for example, sands, silts, clays, etc. The soil to be
4 treated may be wet or comprise sludges, sediments, or ash.

5 [0014] As indicated above, the general vitrification process involves electric melting of
6 contaminated soil or other earthen materials for purposed of destroying organic contaminants
7 and immobilizing hazardous and radioactive materials within a high-integrity, vitrified
8 product. The process is initiated by placing electrodes within the material to be treated,
9 followed by placement of a conductive starter path material between the electrodes. When
10 electrical power is applied, current flows through the starter path, heating it up to the point
11 that it melts the soil and waste adjacent to it. When the adjacent soil and waste becomes
12 molten, they become electrically conductive, and from that point on, the molten material
13 serves as the heating element for the process. Heat is conducted from the molten mass into
14 adjacent un-melted soil and waste, heating it also to the melting point, at which time it
15 becomes part of the heating element. The process continues by increasing the amount of
16 material melted until the supply of electric power is terminated. During the melting or
17 vitrification process, any off gases are captured and, where necessary, treated in a suitable,
18 known manner. The vitrified mass resembles a glass and crystalline product and immobilises
19 non-gassified contaminants such as heavy metals and radionuclides etc. The vitrification
20 process has a high tolerance for debris such as steel, wood, concrete, boulders, plastic,
21 bitumen, tires etc.

22 [0015] For typical soil materials, the melting process is performed in the temperature
23 range of about 1400° to 2000°C, depending primarily on the composition of the materials
24 being melted. Melts of various sizes and shapes can be produced.

25 [0016] In a preferred embodiment of the present invention, the vitrification process
26 involves the use of a steel container such as a "roll-off box", which is commonly available.
27 In accordance with the present invention, the container is first insulated to inhibit
28 transmission of heat, and is also provided with a refractory lining inside the box to protect the
29 box during the melting step. The waste or soil material to be treated is placed within the box.
30 Electrodes are then introduced into the material and the melting process is conducted as
31 described above. Once melting is complete, the contents of the box are allowed to cool and
32 solidify. Subsequently, the box is then disposed of along with the vitrified contents. In an

1 alternate embodiment, the vitrified contents can be removed from the box and disposed of
2 separately, thereby allowing the box to be re-used.

3 [0017] Figure 1 illustrates a treatment container according to one embodiment of the
4 present invention. As illustrated, the container 10 comprises a box having sidewalls 12 and a
5 base 14. The container 10 is provided with a layer of insulation 16 on each of the sidewalls
6 12 and the base 14. After placement of the insulation, the container is lined with a refractory
7 material 18, such as sand. The refractory material is provided so as to line the sides as well
8 as base of the container. In this manner, a space 20 is left into which the material to be
9 treated can be placed. In a preferred embodiment, the refractory material is further lined with
10 a plastic liner 19.

11 [0018] Figure 2 illustrates one embodiment of the present invention. As shown, the
12 container of Figure 1 is provided with a hood 22. The hood 22 is positioned over the
13 container 10 and seals the top thereof. The hood is provided with openings 24 through which
14 extend electrodes 26.

15 [0019] Between the hood 22 and the container 10, may be placed a connector 28, which
16 connects the hood 22 to the container 10.

17 [0020] As shown in Figure 2, after the insulation 16 and refractory material 18 are placed
18 in the container 10, drums of the waste material 30 are then placed within the space 20. The
19 drums may, for example, comprise standard 55 or 30 gallon drums. Void spaces between the
20 drums 30 are filled with soil 32. Such soil, 32, is also provided to cover the drums. Further,
21 a layer of cover soil 34 is placed over the covered drums and extends into the connector 28.
22 An electrode placement tube 36 extends through the cover soil 34. The electrodes 24 for the
23 treatment process extend through the placement tube 36.

24 [0021] Figure 3 illustrates another embodiment of the invention wherein compacted
25 drums 30a or any other waste materials are provided in the container 10 instead of cylindrical
26 drums as shown in Figure 2.

27 [0022] The present invention will now be described in terms of the steps followed. First,
28 the containers are, as described above, lined with a thermal insulation board, followed by
29 placement of a slip form to facilitate the installation of a layer of refractory material (i.e. a
30 material having a very high melting point such as silica sand. A plastic liner is then placed
31 in the container so that waste materials and soil can be staged within the plastic liner. The
32 plastic liner may be used to contain liquids prior to treatment when the waste material to be

1 treated contains appreciable liquids. The slip form may be removed once the waste material is
2 emplaced.

3 [0023] As described below in the example, the waste material to be treated can be placed
4 within the container in drums. Within the drums, the waste material can be compacted to
5 maximize the amount of the material to be treated. Alternatively, in another embodiment, the
6 material to be treated can be placed directly into the container without the need for drums. In
7 another embodiment, the material to be treated can be placed within the container in bags or
8 boxes. In still another embodiment, liquid wastes can be mixed with soil or other absorbents
9 and placed in the container.

10 [0024] In another embodiment, the steel container, as described above, can be placed
11 within a concrete or steel cell prior to the vitrification step. Such concrete cell is provided
12 with the necessary electrical supply and off-gas treatment facilities required for the
13 vitrification process.

14 [0025] As will be understood by persons skilled in the art, various additives may be
15 added to the waste material to improve or enhance the process of the invention. For example,
16 such additives may increase the conductivity of material (e.g. Na^+) or aid in oxidizing metals
17 contained in the material (e.g. sucrose, KMnO_4).

18 [0026] In one embodiment, the containers of the present invention can be standard "roll-
19 off" boxes ranging in volume from 10 to 40 cubic yards. Such containers or boxes will have
20 any variety of dimensions of length, width and height. As will be appreciated by persons
21 skilled in the art, the dimensions of the box will be limited only by the requirements of any
22 apparatus that must be attached thereto. In another embodiment, the container of the
23 invention may comprise metal drums, such as standard 55 gallon steel drums. Such drums
24 can be provided with the required insulation and/or refractory material layers as discussed
25 herein. The wall thickness of the containers of the invention can also vary. Typically,
26 standard boxes have wall thicknesses that are in the range of 10 to 12 gauge; however, as will
27 be apparent to persons skilled in the art, other dimensions are possible.

28 [0027] Typically, the containers of the present invention will be provided with insulation
29 that is in the form of an insulation board that is 1 to 2 inches in thickness. The refractory
30 sand material may be provided in a thickness of 4 to 8 inches and up to 12 inches at the base.

31 [0028] In general terms, the insulation and refractory material form a liner or liner system
32 in the interior of the container. Such liner serves to maintain heat within the container so as

1 to increase the efficiency of the melting process. With this in mind, it will be appreciated that
2 the refractory material, or sand, can also serve as an insulating layer. In such case, the
3 thickness of the refractory material in the container may be increased to provide the needed
4 insulating value. Alternatively, the refractory material may be omitted and only an insulating
5 layer provided in the container. In the case where both a refractory layer and separate
6 insulating layer is used, the refractory material would also serve to direct heat away from the
7 insulating layer. In such case, it would be possible to extract the insulating layers from the
8 container after the vitrification process and re-use them. In another embodiment, multiple
9 layers of insulating and/or refractory liners may be used. As will be understood, the amount
10 of insulating and/or refractory material would depend, amongst other criteria, on the nature of
11 the soil and waste materials being treated. For example, if such soil and material has a high
12 melting temperature, then extra insulating and/or refractory material would be required.

14 Example

15 [0029] The invention will now be described with reference to a specific example wherein
16 radioactive substances, such as uranium, are involved. It will be understood that the example
17 is not intended to limit the scope of the invention in any way.

18 [0030] First, the waste material is placed within 30 gallon drums. The drums, containing
19 the waste material, are then compressed or compacted and placed within 50 gallon drums and
20 packed with soil and sealed. These latter drums are then introduced into the treatment
21 container 10. During the compression of the smaller drums, any oil in the waste material may
22 need to be removed and treated separately, as described further below.

23 [0031] The placement of the compacted drums of material to be treated (e.g. uranium and
24 oil) into the container 10 can be performed in two ways. The first method involves emptying
25 of the 55-gal drums holding the compacted smaller drums and soil into the container 10. The
26 compacted drums would be immediately covered with soil to prevent free exposure to air. In
27 this method, the compacted drums may be staged more closely together for processing, and a
28 higher loading of uranium can be achieved. In addition, by removing the compacted drums
29 from the 55-gal drums, there would be no requirement to ensure that the 55-gal drums were
30 violated or otherwise unsealed so as to release vapours during the vitrification phase.

1 [0032] Alternatively, the 55-gal drums containing the compacted drums could be placed
2 directly into the waste treatment containers for treatment. In this case, vent holes will be
3 installed into the drums to facilitate the release of vapours during processing.

4 [0033] Some of the contaminated oil (11 wt%) removed during the compression phase of
5 the smaller (30 gallon) drums can be added to the soil in the treatment volume in the
6 container for processing with the drums of uranium. The plastic liner 19 will prevent the
7 movement of free oil from the waste materials into the refractory sand materials 18. The slip
8 form will be raised as the level of waste, soil, and refractory sand are simultaneously raised,
9 until the container is filled to the desired level. At that point the slip form will be removed to
10 a storage location.

11 [0034] A layer of clean soil is placed above the staged waste and refractory sand.
12 Electrodes are then installed into the soil layer. The installation of the electrodes may involve
13 the use of pre-placed tubes to secure a void space for later placement of electrodes 26. A
14 starter path is then placed in the soil between the electrodes. Lastly, additional clean cover
15 soil 34 is placed above the starter path 31. This will conclude the staging of the waste within
16 the treatment container. The configuration of the waste treatment containers after waste
17 staging is shown in Figures 2 and 3.

18 [0035] Once the waste treatment container 10 is staged with waste as described above, it
19 is covered with an off-gas collection hood 22 that is connected to an off-gas treatment
20 system. Electrode feeder support frames 27, to support electrode feeders 29, are then
21 positioned over the container-hood assembly 22 unless they are an integral part of the hood
22 22 design, in such case they will already be in position. An electrode 26 is then placed
23 through the feeder 29, into the hood 22 and into the tube 36 placed at the end of the starter
24 path 31. Additional starter path material will be placed within the tube 36 to ensure a good
25 connection with the starter path 31. Finally the remainder of the tube will be filled with clean
26 cover soil 34. This will complete the preparation of materials for melting. It will be
27 appreciated that although the above discussion has been directed to a single electrode, the
28 container will be provided with at least a pair of electrodes, each including similar
29 requirements as indicated above. Indeed, as will be apparent to persons skilled in the art, any
30 number of electrode pairs may be provided in the system.

31 [0036] Commencement of off-gas flow and readiness testing will be performed prior to
32 initiation of the melting process. The melt processing will involve application of electrical

1 power at an increasing rate (start-up ramp) over a period of time and at a given power output
2 value. For example, electrical power may be applied for about 15 hours to a full power level
3 of approximately 500 kW. It is anticipated that processing of waste containing uranium,
4 drums and oil may take a total of two (2) to five (5) days cycle time to complete depending
5 on the type of waste being treated, the power level being employed and the size of the
6 container. Preferably, processing will be performed on a 24-hr/day basis until completed.

7 [0037] Figures 4a to 4d illustrate the progressive stages of melting of the material within
8 the container 10.

9 [0038] Although the invention has been described with reference to certain specific
10 embodiments, various modifications thereof will be apparent to those skilled in the art
11 without departing from the spirit and scope of the invention as outlined in the claims
12 appended hereto.

13

**THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE
PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:**

1. A process for vitrifying waste and/or hazardous material comprising:
 - providing a container for containing said material, said container including an insulating lining;
 - placing said waste or hazardous material in said container;
 - inserting at least one pair of electrodes into said waste or hazardous material;
 - sealing said container with a first cover;
 - passing current between said pair of electrodes for a time and power level so as to melt said waste or hazardous material; and,
 - cooling said molten material until such material forms a solid, vitrified mass.
2. The process of claim 1 further comprising:
 - removing said first cover;
 - re-sealing said container with a second cover;
 - disposing said container containing therein said vitrified mass.
3. The process of claim 1 wherein any gasses generated during said melting step are collected and/or treated before being vented.
4. The process of claim 3 wherein said first cover includes a means to collect said gasses.
5. The process of claim 1 wherein said container includes a further, liquid impermeable inner liner, whereby any liquids contained in said waste or hazardous material is prevented from contacting said refractory material prior to said melting step.
6. The process of claim 1 wherein said waste or hazardous material comprises contaminated soil.

7. The process of claim 6 wherein said waste or hazardous material contains contaminants chosen from the group consisting of hydrocarbons, radioactive materials, radionuclides, carcinogens, or any combination thereof.
8. The process of claim 1 wherein said insulating lining comprises one or more layers of a thermal insulating material, one or more layers of a refractory material or a combination thereof.
9. A container for vitrifying waste or hazardous material comprising a box, said box including an inner lining comprising one or more layers of a thermal insulating material, one or more layers of a refractory material or a combination thereof.

Figure 1

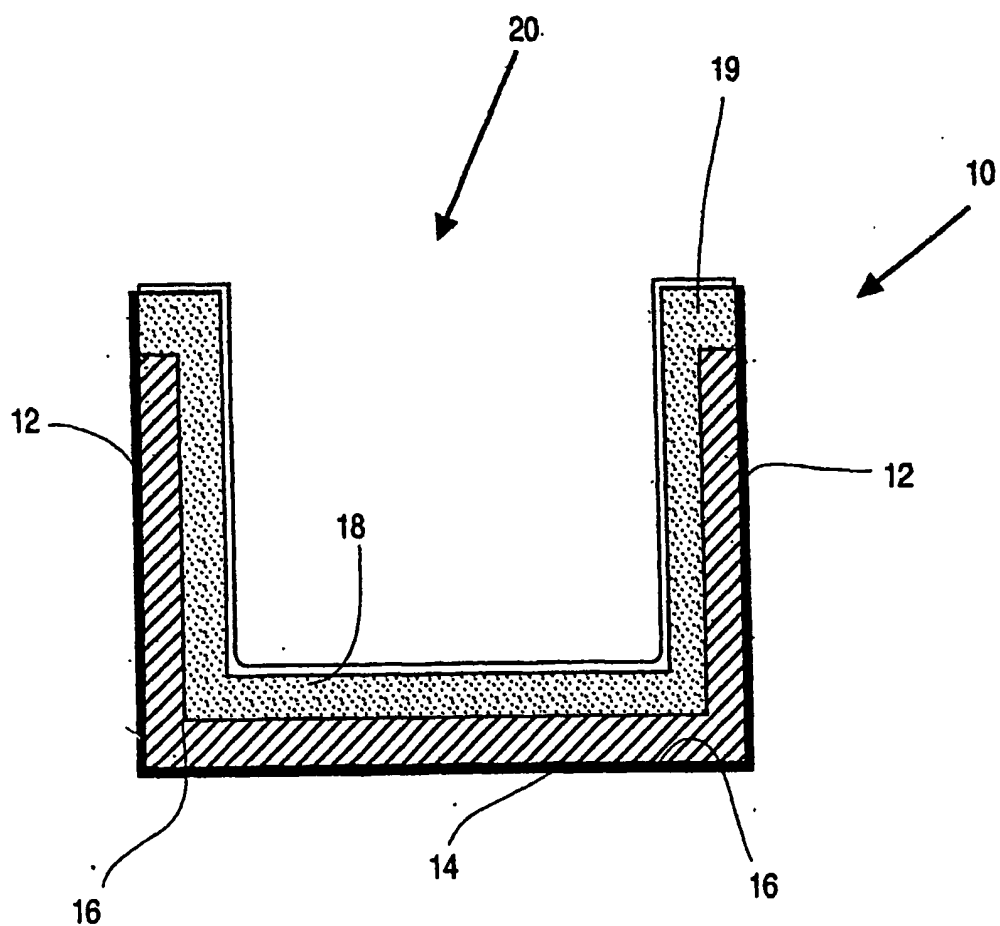


Figure 2

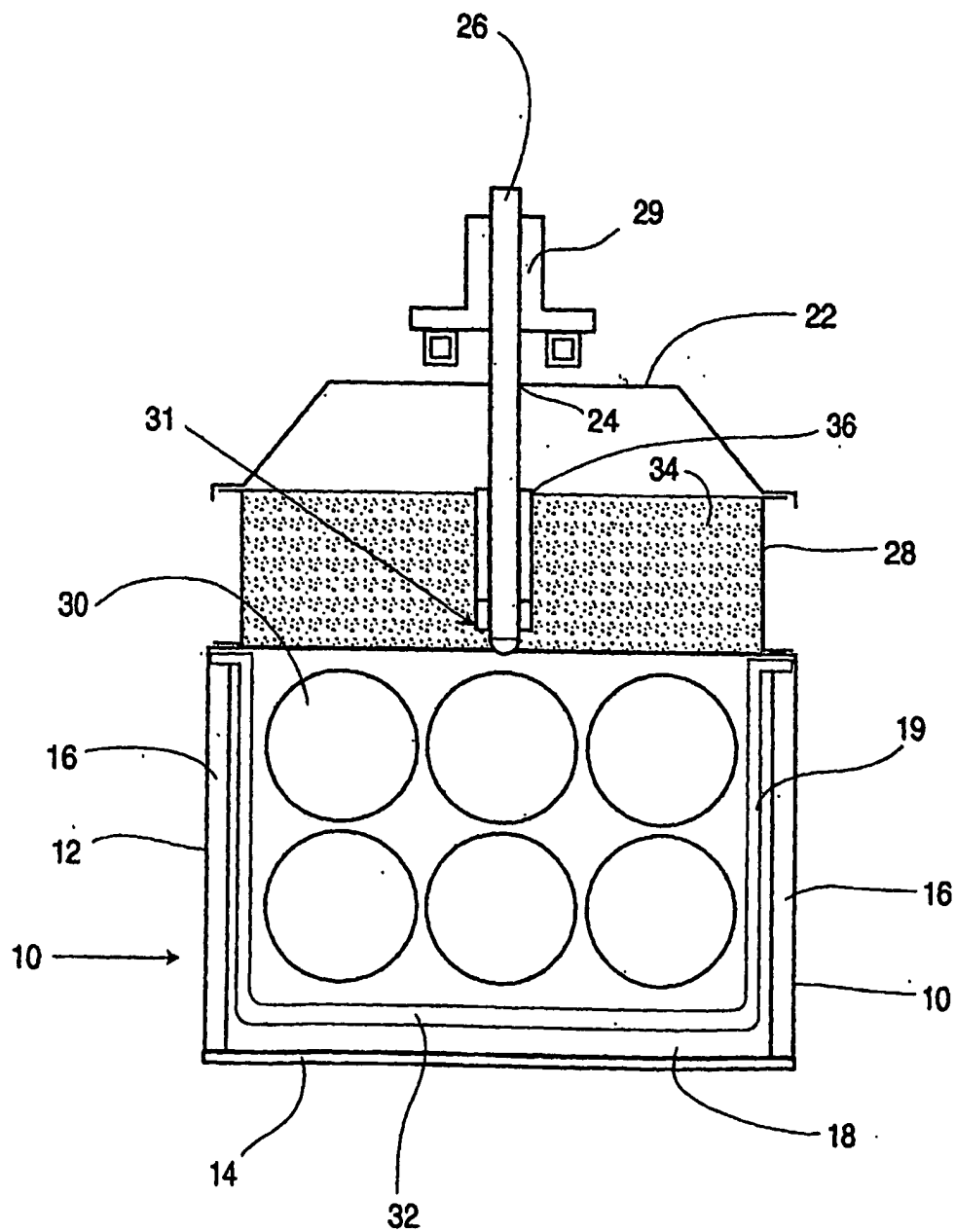
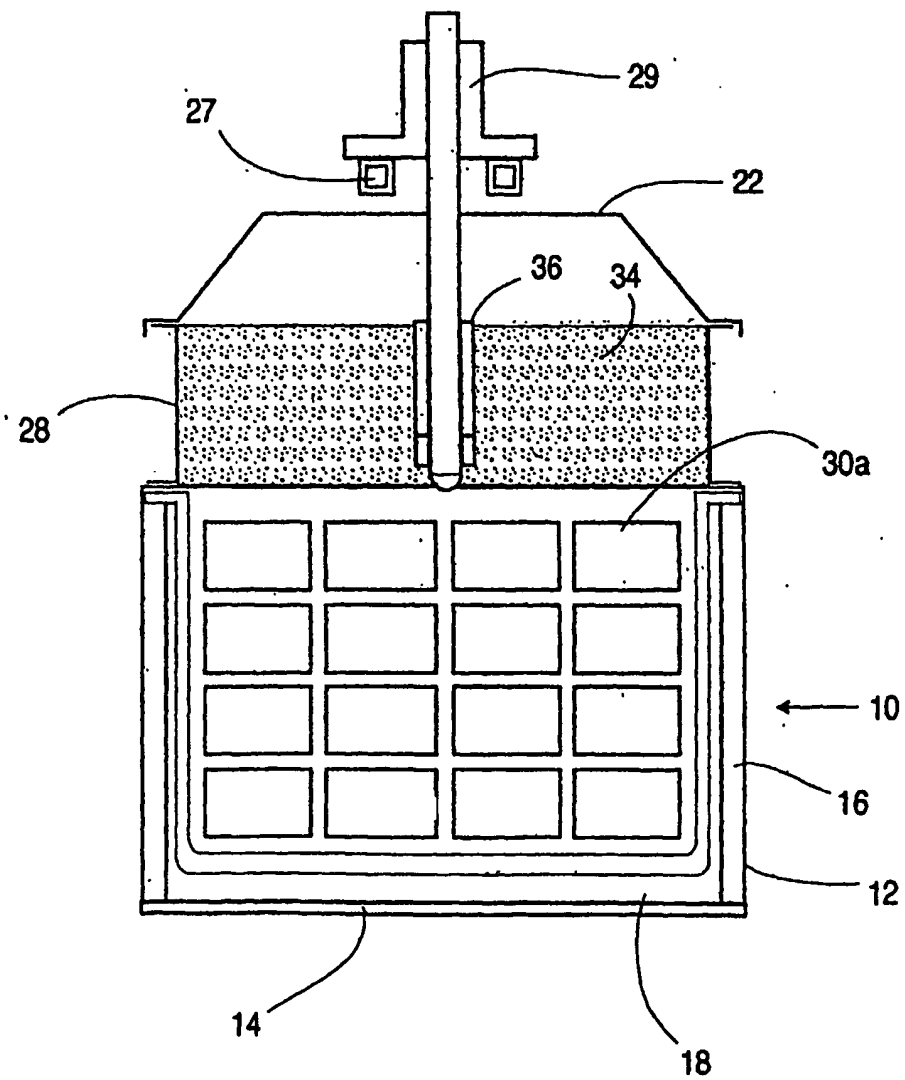


Figure 3



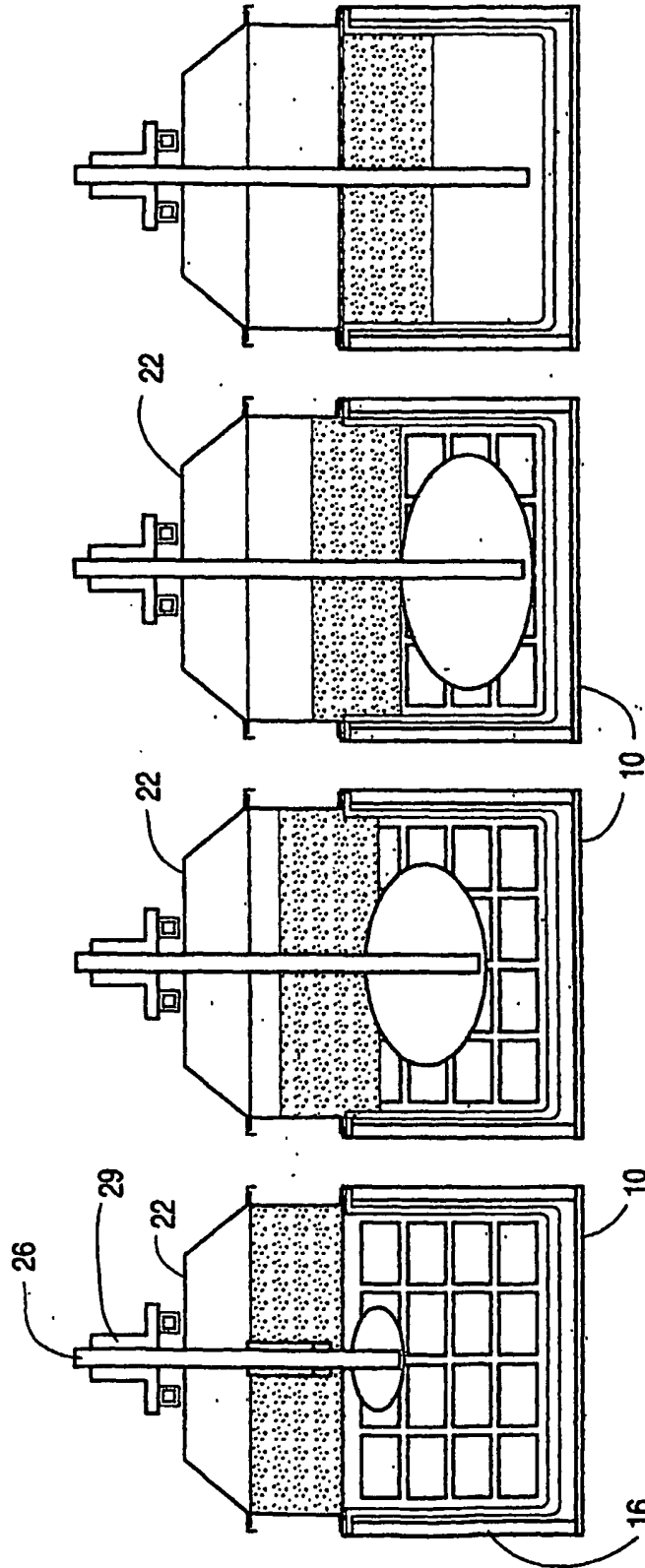


Figure 4D

Figure 4C

Figure 4B

Figure 4A

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US01/42321

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : F27D 17/00

US CL : 373/9

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 373/2,8,9,30,36-3960-62,71-77; 65/27,134.6,136.1; 405/128,258; 588/237

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,673,285 A (WITTLE et al) 30 September 1997, see the entire reference.	1,3-4, and 6-9.
X	US 5,443,618 A (CHAPMAN) 22 August 1995, see the entire reference.	9
X	US 4,660,211 A (STRITZKE) 21 April 1987, see the entire reference.	9
X	US 5,062,118 A (MASAKI) 29 October 1991, see the entire reference.	1, 3-4, and 6-9
A	US 5,319,669 A (COX et al) 07 June 1994, see the entire reference.	1-9
A	US 5,926,498 A (MECHTERSHEIMER) 20 July 1999, see the entire reference.	1-9
A	US 5,536,114 A (WETMORE et al) 16 July 1996, see the entire reference.	1-9

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search

13 December 2001 (13.12.2001)

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Name and mailing address of the ISA/US

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INTERNATIONAL SEARCH REPORT

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Continuation of B. FIELDS SEARCHED Item 3:

EAST, WEST

search terms: vitrifying, waste, electrodes